

## Land Birds on Barrow Island: Status, Population Estimates, and Responses to an Oil-field Development

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### Abstract

A census of land birds on Barrow Island, Western Australia was carried out during September and October 2001. A total of 178 transects was conducted in six major vegetation zones, with 777 individuals of 16 species of birds recorded. The six most common species, in order of their abundance, were Spinifexbird (*Eremiornis carteri*), White-winged Fairy-wren (*Malurus leucopterus*), Singing Honeyeater (*Lichenostomus virescens*), White-breasted Woodswallow (*Artamus leucorhynchus*), Zebra Finch (*Taeniopygia guttata*), and Welcome Swallow (*Hirundo neoxena*). Our total population estimates for these species were generally comparable to those of a survey of Barrow Island in 1976 (Sedgwick 1978), but some differences existed for these and other species. In an analysis of habitat preferences, more complex vegetation zones supported more species. The density of both Spinifexbirds and Singing Honeyeaters was significantly correlated with the number of emergent shrubs. Also, across vegetation zones, the number of different bird species was correlated with the maximum height of vegetation in a habitat. Species richness and numbers of individuals were compared between natural areas, areas surrounding oil pads, and along roadsides. There was no significant difference in species richness across these three areas, but there was a significant increase in number of individuals along road sides. This latter result occurred because disturbed areas along roadsides were colonized by a large species of spinifex, *Triodia angusta*, which supported greater numbers of birds than other species of spinifex away from roads. The oil-field development on Barrow Island occupies approximately 4% of the land area on the island and appears, at present, to have had a relatively minor impact on the populations of land birds. This conclusion is qualified in that several species of insectivorous birds have declined in numbers over the last 25 years, and the reasons for these declines are not yet known.

Keywords: birds, Barrow Island, oil-field development, species diversity

### Introduction

Barrow Island is the second largest island (after Dirk Hartog Island) in Western Australia. Barrow Island experiences a tropical arid climate, and its vegetation is dominated by spinifex (*Triodia* sp.). The ecosystem on Barrow Island is interesting because it has been relatively unimpacted by the negative consequences of human activity and development, a situation unique in Australia and elsewhere. Barrow Island was designated as a Class A Reserve in 1910, which greatly limited human activity. In 1964 an oil-field development began on the island (by Western Australian Petroleum (WAPET), and continues with Chevron Inc. Despite this, however, there are no introduced animal species on the island, the fauna has never been persecuted or hunted, and the terrestrial vertebrates are extremely common.

The avifauna on Barrow Island was surveyed three times during the 20th century: by F. Lawson Whitlock in 1917 and 1918 (Whitlock 1918, 1919), by D. L. Serventy and A. J. Marshall in 1958 (Serventy and Marshall 1964), and by E. H. Sedgwick in 1976 (Sedgwick 1978). Additionally, W. H. Butler has made extensive and long-term observations of the avifauna on Barrow Island

beginning in 1964 and continuing to the present. During this collective work, a total of 113 bird species has been recorded (110 species listed by Sedgwick (1978) plus three additional species recorded by Butler (pers. comm.), and 32 species have been recorded breeding there. Additional work on the avifauna of Barrow Island consisted of an analysis of the diet of insectivorous birds (Wooller and Calver 1981) and a study of breeding chronology (Ambrose and Murphy 1994).

Given the approximate 25 years since the survey by Sedgwick (1978), we sought to conduct a current survey of land birds on Barrow Island, with three objectives: 1. to quantify the occurrence and abundance of species; 2. to document any changes in the avifauna since the survey of Sedgwick (1978); and 3. to quantify the effects of the oil-field development on the island's land birds. Our focus on land birds differs from the complete avifaunal survey of Sedgwick (1978), and this earlier research remains the primary source for a list of all bird species recorded on the island. We focused on land birds because our time on the island was limited and we wanted to obtain an accurate estimate of population densities. We acknowledge that oil-field development can have both direct and indirect consequences for water birds and sea birds as well as land birds but our focus here is only with the island's land birds.



## Study area and methods

### Study area

Barrow Island (20°43'S, 115°28'E) is a continental island, 56 km from the Western Australian coast between Onslow and Port Hedland, and approximately 1300 km north of Perth. It has been isolated from the mainland for 7500 to 8000 years. It was formed from Tertiary limestone, and consists of high coastal cliffs on the west, sloping down through central uplands to coastal plains on the east. The climate is classified as tropical arid, or as a northern monsoonal climate (Gentilli 1972), with seasonally extremely high temperatures (> 45°C), and sporadic and highly variable rainfall. The rainfall averages 330 mm, but in four out of five years, the rainfall averages just 20% of this value. Most of the annual rainfall occurs during cyclones between February and June. Creeks and claypans will hold fresh water after a cyclone, but otherwise freshwater is extremely limited. Heavy dews, however, occur throughout the year (Buckley 1983) and provide a source of fresh water for birds, as do shoreline seeps. Additionally, facilities associated with the oil-field development now contain standing fresh water.

Vegetation on Barrow Island has been studied by several investigators. Butler (1970) identified six major vegetative zones, and Buckley (1983) identified nine major zones, with 29 subtypes. On contract from WAPET, Matiske Consulting Group produced a detailed vegetation map of the island, identifying six major terrestrial vegetation types and 31 subtypes (excluding marine and two tidal vegetation zones). Our work and analyses were based on this latter map. A digital version of this map was available from National Geographic Information Systems (NGIS, Perth, Western Australia), and under contract, NGIS produced a field map of the vegetation zones for our use and calculated the area occupied by each zone, as well as areas occupied by various types of development (roads, oil wells, etc.).

Briefly, the six land forms/vegetation units were: coastal complexes and dune systems (type C in Table 1, creeks or seasonal drainage lines (D), flats (F), limestone ridges (L), clay pans (S), and valley and escarpment slopes (V). *Triodia* hummock grassland is the dominant vegetation type and *Triodia* sp. occurs over 93% of the island. A complete list and description of each vegetation type, and subtype, is available on request from the authors.

Because we wanted to calculate total population densities for the common land birds, we needed to calculate the total habitat area (land area) available to birds on Barrow Island. To do this, we corrected each vegetation zone for the area in each zone that was taken up by the presence of roads, oil pads, etc. We corrected the area measurements as follows: the total area of Barrow Island is 23 452.9 ha (measured from the high tide mark). Of this area, 161.3 ha (0.69%) consist of bare sand, marine and tidal habitats (which were not censused and in which there were no disturbances), or large areas with no vegetation, such as the airport and main Chevron camp. This leaves a total area of 23 291.6 ha encompassing the six major vegetation zones surveyed in this study, and also the area in which all of the

disturbances associated with the oil-field development were located (excluding the airport and camp). The total area of disturbed areas (again excluding the airport and camp) is 915.7 ha or 3.93% of the total area. This includes the area occupied by 821 oil wells (as of 1997), and approximately 550 km of roads. In correcting the areas of each vegetation zone, we reduced the area by 3.93% to account for the disturbance in that zone. We recognize that this correction makes the assumption that disturbances are distributed randomly across vegetation zones, which is not correct. It would be logistically impossible to precisely calculate how much of each vegetation zone is disturbed, however we believe that our correction provides as accurate a calculation of the available habitat area as is possible. We also fully recognize that land birds do use roads and other man-made structures (although no birds were seen to use oil wells as 'habitat'). Nevertheless, our correction of the area of each vegetation zone by the amount of disturbed area within that zone seemed to us as the most conservative solution in order to calculate overall population estimates.

### Methods

Fieldwork was conducted from 14 September 2000 to 12 October 2001. A census was carried out on birds via transects in quadrats in each of the 31 vegetation zones. Our initial goal was to carry out a census in six quadrats within each vegetation zone, but in some cases this was not possible because some habitats were limited in area. Although the quadrats were located in specific vegetation zones, we made a concerted effort to census birds in all areas of the island. A total of 178 quadrats were censused.

The transect counts were conducted each morning, weather permitting, from 0545 to 1100 and again from 1500 to 1700. The quadrats were 2 ha in size, and in most cases were 200 m long X 100 m wide. The length of the quadrat was determined using a portable GPS unit (Garmin 45; accuracy = 10 m). The width of the quadrat was estimated visually. In order to maintain accuracy, both observers practiced estimating 50 m lengths and then checked these distances with a tape measure. We surveyed each quadrat together. One of us walked slowly in a straight line down the middle of the quadrat, and the other person zigzagged through the quadrat, intersecting the path of the person walking straight every 50 m. All birds seen or heard inside the quadrats were counted. Each individual bird that was recorded was noted by both observers to ensure that it was only recorded once. A census was carried out in each quadrat only once, and all censuses took approximately 10 min to conduct (range 9–13 min).

The exceptions to our methods as described above were as follows: first, in narrow, and linear vegetation zones, e.g., coastal habitats, the transects were 400 m long and 50 m wide; second, in habitats with dense and large spinifex both observers walked straight lines through the quadrats in parallel lines 40 m apart.

As most vegetation zones were characterized by low plant height, and discontinuous distributions of plants, all bird species were equally detectable and we believe



that we counted all birds using the quadrats. In areas with continuous and dense spinifex, the spinifexbird was sometimes difficult to detect because it often hid within large spinifex plants. In such situations, it was possible that we missed a few individual spinifexbirds although we made every effort possible to detect all individuals present.

We calculated total population estimates for all 16 species recorded on transects (see Results). The estimates were made as follows: (population density in each vegetation zone)/(proportion of total area of each zone that was surveyed during quadrat transects), summed over all vegetation zones = total population estimate.

Besides conducting transects in natural, undisturbed areas, we also carried out a census of birds around oil pads (the raised or leveled areas on which there was a Lufkin oil pump) and also along roads. The oil pad and road censuses were conducted as described above, with the following exceptions: first, the oil pad quadrats consisted of abutting rectangles at right angles to each other (either two or three, two ha total area) that were oriented so that they surrounded the oil pad; and second, the road side quadrats consisted of two areas 200 m long x 50 m wide (two ha total area) on either side of the road. For the roadside transects, censuses were carried out in both areas on either side of the road simultaneously, with each of us walking along a mid-line of the quadrat. The oil pad and road transects were conducted in four vegetation zones as follows: L1 (hummock grassland of *T. wiseana* with *Ficus platypoda* on central limestone ridges); L3 (hummock grassland of *T. wiseana* with low mixed shrubs including *A. gregorii* on limestone ridges); L7 (hummock grassland of *T. wiseana* with dense pockets of *M. cardiophylla* on limestone ridges); and V1 (hummock grassland of *T. wiseana* with mixed emergent shrub species on valley slopes). These four habitats were chosen because they were the most common habitats on the island and because the majority of oil pads and roads associated with the oil-field development were located in these habitats.

We took vegetation measurements on each quadrat to quantify large-scale differences between vegetation types. At the starting point of each transect, and at every 50 m (5 points total) we measured vegetation cover and vegetation height. Vegetation cover was measured at ground level and was scored as the number (percentage) of 1 cm squares of a 1 m long stick that was covered by living vegetation. In addition, for the entire quadrat as a whole, we measured the height of the tallest tree or shrub (maximum vegetation height) and also counted the number of emergent shrubs. Emergent shrubs were defined as woody shrubs that were at least 50% taller than the surrounding vegetation. This relative measure was necessary because the height of the spinifex, which covered the ground in most areas, varied greatly in height (e.g., from 0.3 m for *T. wiseana* to 1.5 m for *T. angusta*). The number of emergent shrubs was scored as 1 (0 emergent shrubs), 2 (1–10 emergent shrubs), 3 (10–25 emergent shrubs), 4 (25–50 emergent shrubs), and 5 (50+ emergent shrubs).

In addition to counting birds on the quadrats, we also recorded birds seen outside the quadrats during the formal counts, and also during general fieldwork during our time on the island.

## Results

### Avifauna

During transects, 777 individuals of 16 species were recorded. Two additional species, the Black-shouldered Kite and Richard's Pipit (see below) were observed during general fieldwork, but not recorded on transects. An assessment of the status of each of these 18 species is presented below. Our definitions of status is: common = an abundant species (>10 individuals recorded on quadrats), seen in many habitats across the island; uncommon = a species only occasionally seen (3–10 individuals recorded on quadrats), or restricted to specific habitats; rare = a species for which just a few individuals were seen (1–2 individuals recorded on quadrats), and/or a species that was restricted to just one or two habitat types.

- Spotted Harrier (*Circus assimilis*): Uncommon; individuals occasionally seen inland; scattered along coast.
- Brahminy Kite (*Haliastur indus*): Rare; pairs occasionally seen inland off the quadrats; scattered along coast.
- Osprey (*Pandion haliaetus*): Rare on quadrats; pairs regularly spaced around coastline; not seen inland but we received reports that individuals will cross the island (W. H. Butler, pers. comm.). All individuals we recorded were seen within 1 km of the coastline. Nesting pairs were observed using both natural sites and nesting platforms erected by WAPET.
- White-breasted Sea-Eagle (*Haliaeetus leucogaster*): Rare on quadrats; pairs occasional along coastline; not seen inland, but we received reports that individuals regularly hunt inland especially near hills (W. H. Butler, pers. comm.). Nesting pairs seen on southern coast.
- Black-shouldered Kite (*Elanus caeruleus*): Rare; not seen on quadrats; two individuals seen on island during fieldwork.
- Australian Kestrel (*Falco cenchroides*): Rare; individuals occasionally seen inland; not seen along coast, although this species is known to nest on coastal cliffs (W. H. Butler, pers. comm.).
- Bar-shouldered Dove (*Geopelia humeralis*): Common in central limestone ridges in valleys, less so on flats and in coastal area; known to nest on limestone ledges, caves, in mangroves and *Acacia* sp. along the coast (W. H. Butler, pers. comm.).
- Black-eared Cuckoo (*Chrysococcyx osculans*): Rare, but scattered throughout island in habitats with emergent shrubs and trees.
- Horsfield's Bronze-Cuckoo (*C. basalis*): Uncommon, but scattered throughout island in habitats with emergent shrubs and trees.
- Sacred Kingfisher (*Todiramphus sanctus*): Rare; only seen along creeks and drainage lines.
- Welcome Swallow (*Hirundo neoxena*): Common and widespread; common around developed areas, less so elsewhere. Many nesting pairs observed at camp and airport.

- Tree Martin (*H. nigricans*): Rare; only one individual seen.
- Australian Pipit (*Anthus australis*): Rare; not seen on quadrats; seen on two occasions in low limestone ridges along coast.
- Spinifexbird (*Eremiornis carteri*): Common; the most abundant species on island; in all habitats with spinifex. Many pairs were breeding.
- White-winged Fairy-wren (*Malurus leucopterus*): Common; abundant in most habitats, especially those with complex vegetation structure. Many pairs were breeding.
- Singing Honeyeater (*Lichenostomus virescens*): Common; abundant in all habitats with dense vegetation or with emergent shrubs and trees. Many pairs were breeding.
- Zebra Finch (*Taeniopygia guttata*): Common on clay pans; uncommon in other habitats.
- White-breasted Woodswallow (*Artamus leucorhynchus*): Common; abundant in all habitats with dense vegetation or with emergent shrubs and trees.

In Table 1 we list, for each of the six land forms/vegetation units, the number of species and individuals recorded, as well as the estimated densities of the six common species. Across all vegetation types together, the density of birds averaged 2.20 birds/ha. Across the 31 vegetation types, there was a significant correlation between the area of habitat that we surveyed and the total number of species ( $F_{1,29} = 11.585, R^2 = 0.261, P = 0.002$ ) and total number of individuals ( $F_{1,29} = 79.588, R^2 = 0.724, P < 0.001$ ) recorded. Similarly, there was a significant relationship between the total number of species and number of individuals recorded on the transects ( $F_{1,29} = 36.289, R^2 = 0.541, P < 0.001$ ).

Total population estimates for all 16 species recorded on quadrats are presented in Table 2, along with the population estimates for these same species published in Sedgwick (1978).

Habitat Relations

Land birds were distributed across the entire island, but both species diversity and abundance varied with habitat (Table 1). Each of the common species observed in this study was found in a variety of habitats, but densities varied considerably (Table 1).

For the 31 vegetation types separately, we examined whether any of the habitat variables correlated with number of species and individuals recorded, and with the densities of the six common bird species (Table 1). A complete summary of habitat measurements and species abundances on each of the 31 vegetation subtypes is available on request from the authors. There was no significant correlation between any of the habitat variables and species richness, or total number of individuals. Nevertheless, several significant relationships between habitat measurements and densities of individual species emerged: the density of Spinifexbirds was significantly correlated with the mean emergent score ( $F_{1,29} = 11.046, P = 0.002$ ) and with vegetation cover ( $F_{1,29} = 5.393, P = 0.027$ ; Fig. 1). The density of Singing Honeyeaters was significantly related

Table 1

Summary of quadrat results and densities of the six most common passerines.

| Vegetation                            | Birds recorded      |                    |         | Densities of most common species (birds/ha) |              |                         |                    |                            |             |                 |
|---------------------------------------|---------------------|--------------------|---------|---------------------------------------------|--------------|-------------------------|--------------------|----------------------------|-------------|-----------------|
|                                       | Area on island (ha) | Area surveyed (ha) | Species | Number                                      | Spinifexbird | White-winged Fairy-wren | Singing Honeyeater | White-breasted Woodswallow | Zebra Finch | Welcome Swallow |
| C-coastal complex and dune systems    | 1,473.8             | 56                 | 10      | 169                                         | 1.43         | 0.48                    | 0.64               | 0.12                       | 0.07        | 0.16            |
| D-Creeks or drainage lines            | 1,089.9             | 18.6               | 9       | 56                                          | 1.29         | 0.59                    | 0.27               | 0.22                       | 0.22        | 0.22            |
| F-Flats                               | 3,865.5             | 58                 | 9       | 144                                         | 1.38         | 0.24                    | 0.33               | 0.26                       | 0.05        | 0.16            |
| L-Limestone ridges                    | 9,067.6             | 164                | 12      | 297                                         | 1.07         | 0.37                    | 0.19               | 0.05                       | 0.02        | 0.02            |
| S-Clay pans                           | 185.6               | 10.9               | 6       | 47                                          | 0.37         | 0.46                    | 0.18               | 0.64                       | 1.65        | 0.01            |
| V-Valley slopes and escarpment slopes | 6,693.2             | 46                 | 4       | 64                                          | 0.89         | 0.30                    | 0.17               |                            |             |                 |
| TOTALS                                | 22,375.60           | 353.5              | 16      | 777                                         | 1.14         | 0.37                    | 0.29               | 0.12                       | 0.09        | 0.10            |



Table 2

Number of individuals of each species recorded on quadrats and total population estimates for Barrow Island in comparison with the estimates of Sedgwick (1978).

| Species                    | Quadrat counts | Total population estimate based on this study | Population estimate from Sedgwick (1978) |
|----------------------------|----------------|-----------------------------------------------|------------------------------------------|
| Spotted Harrier            | 3              | 162                                           | 180                                      |
| Brahminy Kite              | 2              | 23                                            | 15                                       |
| Osprey                     | 1              | 73                                            | 180                                      |
| White-breasted Sea-Eagle   | 1              | 73                                            | 3                                        |
| Australian Kestrel         | 1              | 69                                            | 1,650                                    |
| Bar-shouldered Dove        | 14             | 692                                           | 180                                      |
| Black-eared Cuckoo         | 2              | 67                                            | No estimate                              |
| Horsfield's Bronze-Cuckoo  | 5              | 102                                           | 910                                      |
| Sacred Kingfisher          | 1              | 6                                             | 12                                       |
| Welcome Swallow            | 36             | 1,077                                         | 8,500                                    |
| Tree Martin                | 1              | 6                                             | 7,050                                    |
| Spinifexbird               | 404            | 24,623                                        | 17,800                                   |
| White-winged Fairy-wren    | 132            | 7,519                                         | 8,150                                    |
| Singing Honeyeater         | 101            | 3,920                                         | 3,050                                    |
| Zebra Finch                | 32             | 1,152                                         | No estimate                              |
| White-breasted Woodswallow | 41             | 1,945                                         | 3,450                                    |

to maximum vegetation height ( $F_{1,29} = 10.913, P = 0.025$ ) and to the mean emergent score ( $F_{1,29} = 5.860, P = 0.022$ ).

We combined data from each of the six major habitat zones to examine broad scale habitat relationships within the avifauna. We compared species number, total number of individuals, and mean bird density across these six habitat zones according to each of the habitat variables. The number of species recorded in each habitat was significantly correlated with maximum vegetation height (Spearman Rank Correlation  $R_s = 0.929, P = 0.038$ ) but no other significant correlations were observed.

Effects of Oil-field Development

Our study of the effects of the oil-field development was limited to four vegetation zones as described in

Methods: three limestone ridge habitats (L1, L3, and L7) and one valley habitat (V1).

We first examined whether within each of these habitat types, the vegetation differed between natural areas, around oil-pads, and along roadsides. Within habitat L1, there was significant variation in vegetation cover between these areas ( $F_{2,87} = 4.363, P = 0.016$ ), with natural areas supporting significantly lower vegetation cover than either the areas around oil-pads ( $P = 0.027$ ) and along roads ( $P = 0.006$ ); vegetation cover did not differ significantly between oil-pads and along roads. No other difference was detected within habitat L1. In both habitats L3 and L7, there were no significant differences in vegetation measurements across the three areas. In habitat V1, there was significant variation in the number

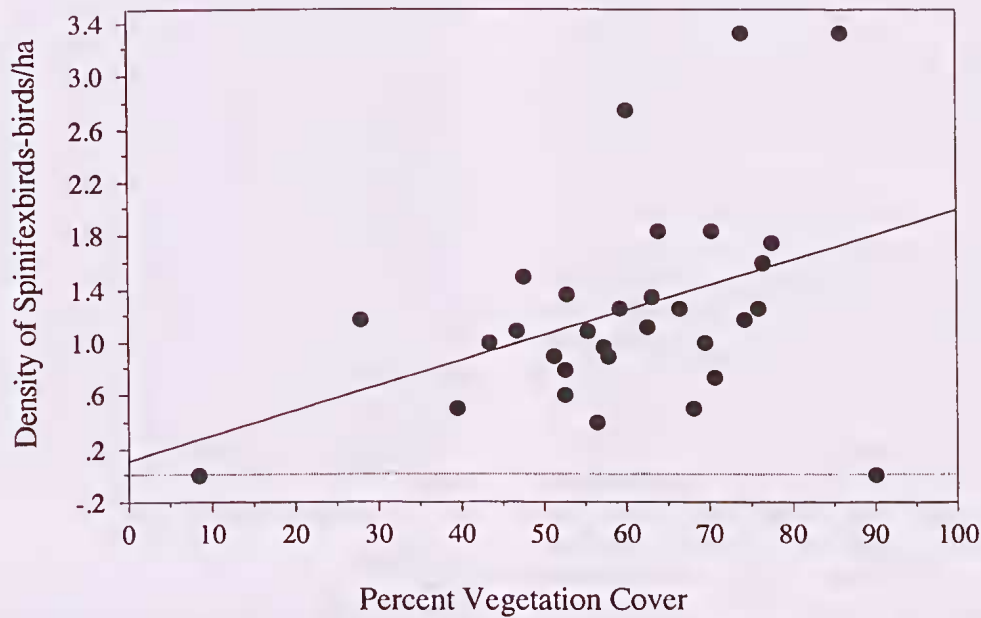


Figure 1. Relationship between mean percent vegetation cover in habitats and the density of Spinifexbirds. The correlation is statistically significant (see text).

of emergent shrubs on quadrats ( $F_{2,15} = 3.961$ ,  $P = 0.042$ ), with natural areas having more emergents than the areas around oil-pads ( $P = 0.0132$ ). Also, mean vegetation height differed significantly between the three areas ( $F_{2,87} = 8.724$ ,  $P = 0.004$ ), with vegetation in natural areas significantly taller than around oil-pads ( $P = 0.0002$ ) and along roads ( $P = 0.0013$ ). Thus, comparison of vegetation measurements between natural and disturbed areas varied with the specific habitat type.

The census results conducted in the four vegetation zones were analyzed in two ways. First, across the four vegetation zones, there was no significant variation in either the number of species ( $F_{3,8} = 1.961$ ,  $P = 0.198$ ) or number of individuals ( $F_{3,8} = 1.620$ ,  $P = 0.620$ ) recorded according to area sampled (natural areas, oil-pads, roadsides). Second, we asked whether, regardless of vegetation zone, species richness and number of individuals varied between natural areas, oil-pads, and roadsides. Although there was no significant variation in number of species recorded ( $F_{2,9} = 0.864$ ,  $P = 0.454$ ), there was significant variation in number of individuals recorded ( $F_{2,9} = 4.922$ ,  $P = 0.036$ ). Roadsides supported significantly greater numbers of individuals than natural areas ( $P = 0.013$ ) and oil-pads (although not significantly so,  $P = 0.077$ ). The number of individuals did not differ significantly between natural areas and oil-pads ( $P = 0.301$ ).

## Discussion

### Avifauna

Of the 110 bird species recorded on Barrow Island and reported by Sedgwick (1978), 48 were land birds. These 48 species included 15 permanent residents, six regular migrants, and 27 irregular visitors. Of the 15 species that Sedgwick considered to be residents, the only species that we did not observe was the Southern Boobook (*Ninox novaeseelandiae*). Our quadrat counts were conducted during daylight hours and thus it is not surprising that we not detect this species on the quadrats. Nevertheless, we did do considerable driving at night, and this species was neither heard nor observed. Additionally, W. H. Butler (pers. comm.) reports that the Southern Boobook is no longer resident on the island. Of the 18 species that we recorded, four species were considered by Sedgwick to be non-residents: the Zebra Finch and Black-eared Cuckoo were considered to be irregular visitors, and the Horsfield's Bronze Cuckoo and Sacred Kingfisher were considered to be regular migrants. Considering these species in turn, the Zebra Finch now appears to be a regular migrant to the island and breeds there every year (L. McClements, pers. comm.). The Black-eared Cuckoo is now known to be an irregular migrant, and Horsfield's Bronze Cuckoo a regular migrant (W. H. Butler and R. Johnstone, pers. comm.). Both species are widespread on the island during the breeding season, and both undoubtedly commonly breed there (see Pruett-Jones and Tarvin 2001). We have no observations or other information to contradict the status of the Sacred Kingfisher as a regular migrant.

Sedgwick recorded four other species as regular migrants that we did not observe: the Pallid Cuckoo

(*Cuculus pallidus*), the White-throated Needle-tail (*Hirundapus caudacutus*) which is listed as the Spine-tailed Swift in Sedgwick (1978), the Fork-tailed Swift (*Apus pacificus*), and the White-winged Triller (*Lalage tricolor*). Records of these species have been scattered since ornithological observations on Barrow Island began and none of these species were recorded by Whitlock (1918, 1919) or Serventy and Marshall (1964). It appears that the Pallid Cuckoo and White-winged Triller are both passage migrants to Barrow Island and the two swift species irregular visitors from Asia (R. Johnstone, pers. comm.).

All other land birds listed by Sedgwick and not observed during this study or discussed above (25 species total) are irregular visitors and do not breed on Barrow Island. This list includes some species that could occasionally breed on the island (e.g., Whistling Kite (*Haliastur sphenurus*) and Wedge-tailed Eagle (*Aquila audax*; the record by Sedgwick is now thought to be a mis-identified juvenile White-breasted Sea-Eagle)) as well as species that are accidental occurrences on the island and do not breed there (e.g., Galah (*Cacatua roseicapilla*) and Little Corella (*C. pastinator*)). The number of such accidental species visiting the island or blown over to the island during storms will likely increase as observations continue on the island.

Sedgwick (1978) calculated total population estimates for all of the species he recorded on his quadrats, as did we in this study (Table 2). There are several points of comparison to make. First, we concur with Sedgwick that the estimates for the Osprey are too high. This is a maritime species that can be seen from inland habitats, but inland habitats such as is available on Barrow Island cannot be considered as regular habitat of this species. At the time of Sedgwick's survey, 23 Osprey nests were known on the island, and although we did not attempt to count Osprey nests we suspect that there are approximately this number of active nests still present. Similarly, we believe our estimate of the total population of White-breasted Sea-Eagle is too high, for the same reasons as outlined above. At the time of Sedgwick's survey, six sea-eagle nests were known on the island, and during our work we had reported to us the locations of five nests. More accurate population estimates for the Osprey would be approximately 50 birds and for the White-breasted Sea-Eagle, 10–12 birds.

For the three most common species (Spinifexbird, White-winged Fairy-wren, and Singing Honeyeater), our total population estimates and those of Sedgwick (1978) are comparable (Table 2). For many of the other species, there are striking differences. In some cases these differences are easily explainable. For example, the Zebra Finch is clearly now more common on Barrow Island than it was during the work of Sedgwick (W. H. Butler, pers. comm.), as reflected in our results and estimates. Also, if resident numbers of the migratory Black-eared Cuckoo and Horsfield's Bronze Cuckoo fluctuate from year to year, the differences between our estimates and those of Sedgwick (1978) may reflect annual variation in the size of breeding populations.

For other species listed in Table 2, the differences between our estimates and those of Sedgwick appear to reflect population declines. The most striking example is the Tree Martin, listed by Sedgwick as the fourth most abundant species on the island (but see Storr 1984), and



yet we recorded just one individual on our quadrats. This species, and two other aerial insectivores (Welcome Swallow and White-breasted Woodswallow) appear to have declined in numbers. Assuming this trend relates to insect abundance, it is not yet clear whether it is a short-term trend reflecting annual variation in insect populations or a long-term trend, with broad ecological implications. If, on Barrow Island, the diet of Australian Kestrels is primarily insectivorous, it could be said that a total of four insectivorous species have shown population declines. Notably, however, the three most abundant species (Spinifexbird, White-winged Fairy-wren, and Singing Honeyeater) are either obligatory or primarily insectivorous, and the populations of these species have not declined (Table 2).

Despite the distance of Barrow Island from the mainland, and the relatively long time it has been isolated, there is only one endemic subspecies of bird that resides there, the White-winged Fairy-wren (*M. l. edouardi*, Ford 1987; Schodde and Mason 1999) and genetic analysis (Driskell et al. 2002) has confirmed the genetic basis of this subspecific designation. Another unique subspecies of the White-winged Fairy-wren (*M. l. leucopterus*) is found on Western Australia's largest island, Dirk Hartog Island. Wooller et al. (1985) suggested that the Barrow Island population of the Singing Honeyeater may be an endemic subspecies, based on vocalizations and measurements, but Schodde and Mason (1999) did not separate the Barrow Island population from the mainland subspecies *L. v. sonorous*, although the basis for that decision is unclear. No genetic analysis of Singing Honeyeaters from Barrow Island has been conducted.

#### Habitat relations

In this study we did not examine specific habitat preferences of individual species, but rather broad differences in habitat types and how these related to species richness and abundance of birds. All habitat types on Barrow Island, with the exception of clay pans, drainages, and coastal areas are dominated by spinifex. All species that regularly feed on the ground or in vegetation, e.g. Spinifexbird, Singing Honeyeater, and White-winged Fairy-wren, used spinifex plants, but these species also seemed to prefer habitats in which spinifex was interspersed with shrubs and trees. Across habitat types, species richness was correlated with maximum vegetation height, indicating that more structurally diverse habitats supported more species. Furthermore, Spinifexbirds were more abundant in areas with greater cover and more emergent shrubs, and Singing Honeyeaters were more abundant in areas with taller vegetation. Spinifexbirds preferred the densest vegetation of any of the species, and rarely emerged from the spinifex. The greater density of Spinifexbirds in areas with emergent shrubs may be related to variation in insect abundance in areas of greater plant diversity.

#### Effects of oil-field development

The effect of the oil-field development on land birds on Barrow Island is difficult to accurately assess in a short-term study such as ours. Approximately 4% of the land area on Barrow Island has been altered, but this has had both positive and negative effects on the land birds.

Positive effects include more nesting sites for some species (e.g., swallows and woodswallows nesting on buildings, ospreys nesting on utility poles) and increased availability of fresh water for some species (e.g., Zebra Finches), whereas negative effects include loss of habitat, altered habitat around man-made structures, etc.

In our comparison of species diversity in natural areas and altered areas, habitat along road sides supported more individuals (but not more species) than natural areas. We believe the reasons for this difference had to do with the effects of disturbance in a *Triodia* dominated habitat. When an area was disturbed, it appeared that the largest species of *Triodia* on Barrow Island, *T. angusta*, rapidly colonized the disturbed area, often times regardless of the dominant surrounding vegetation. For example, in limestone ridge areas, where the small (approximately 0.3–0.5 m high) *T. wiseana* dominated natural vegetation, along the roads there was a two to three m wide area on either side of the road where *T. angusta* occurred, often up 1.5–2.0 m high. Larger, and denser *T. angusta* provided suitable habitat for more individual birds.

As a Class A Nature Reserve, no camping or landing by boaters is allowed on Barrow Island. The only allowed human activity on the island is that associated with the oil-field development and the present leaseholder (Chevron Inc.) controls all human activity on the island. To date, that control and strict quarantine practices for people and vehicles traveling to the island, has acted to protect the Barrow Island ecosystem. Barring the obvious possibility of a damaging oil spill, the avifauna on Barrow Island and the ecosystem itself should continue in its relatively undisturbed condition. When the oil-field is decommissioned, which is likely within the next 10–20 years, the decision on the future of Barrow Island will obviously set the stage for any possible future changes. Given the unique ecosystem on the island, great care should be taken to insure that no future human activity threatens the island.

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